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UTILITY PATENT APPLICATION TRANSMITTAL (Only for new nonprovisional applications under 37 CFR 1.53(b))	Attorney Docket No.	20676-712	Total Pages	45
	First Named Inventor or Application Identifier			
	Oliver P. LEISTEN, "An Antenna"			
	Express Mail Label No.	EM089310828 US		

APPLICATION ELEMENTS See MPEP chapter 600 concerning utility patent application contents.	ADDRESS TO: Assistant Commissioner for Patents Box Patent Application Washington, DC 20231
1. <input checked="" type="checkbox"/> Fee Transmittal Form (Submit an original, and a duplicate for fee processing)	6. <input type="checkbox"/> Microfiche Computer Program (Appendix)
2. <input checked="" type="checkbox"/> Specification [Total Pages <u>27</u>] (preferred arrangement set forth below) <ul style="list-style-type: none">- Descriptive title of the Invention- Cross References to Related Applications- Statement Regarding Fed sponsored R&D- Reference to Microfiche Appendix- Background of the Invention- Brief Summary of the Invention- Brief Description of the Drawings- Detailed Description- Claim(s)- Abstract of the Disclosure	7. Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary) <ul style="list-style-type: none">a. <input type="checkbox"/> Computer Readable Copyb. <input type="checkbox"/> Paper Copy (identical to computer copy)c. <input type="checkbox"/> Statement verifying identify of above copies
3. <input checked="" type="checkbox"/> Drawing(s) (37 CFR 1.152) [Total Sheets <u>2</u>]	8. <input checked="" type="checkbox"/> Assignment Papers (cover sheet & documents(s))
4. <input checked="" type="checkbox"/> Oath or Declaration [Total Pages <u>2</u>] <ul style="list-style-type: none">a. <input type="checkbox"/> Newly executed (original or copy)b. <input checked="" type="checkbox"/> Copy from a prior application (37 CFR 1.63(d)) (for continuation/divisional with Box 17 completed) [Note Box 5 below]<ul style="list-style-type: none">i. <input type="checkbox"/> DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).	9. <input type="checkbox"/> 37 CFR 3.73(b) Statement (when there is an assignee) <input checked="" type="checkbox"/> Power of Attorney by Assignee
5. <input checked="" type="checkbox"/> Incorporation By Reference (useable if Box 4b is checked) The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.	10. <input type="checkbox"/> English Translation Document (if applicable)
	11. <input type="checkbox"/> Information Disclosure Statement (IDS)PTO-1449 [] Copies of IDS Citations
	12. <input checked="" type="checkbox"/> Preliminary Amendment (10 pages)
	13. <input checked="" type="checkbox"/> Return Receipt Postcard (MPEP 503) (Should be specifically itemized)
	14. <input type="checkbox"/> Small Entity Statement(s) [] Statement filed in prior application, Status still proper and desired
	15. <input type="checkbox"/> Certified Copy of Priority Document(s) (if foreign priority is claimed)
	16. <input type="checkbox"/> Other:

17. If a CONTINUING APPLICATION, check appropriate box and supply the requisite information:

☒ Continuation [] Divisional [] Continuation-in-part (CIP) of prior application No. 08/351,631

16. CORRESPONDING ADDRESS

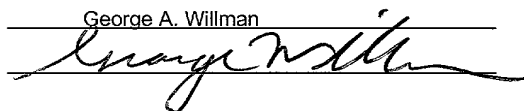
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Date December 3, 1998

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PATENT
Attorney Docket No.: 20676.712

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application)	
)	
Inventor: Oliver Paul Leisten)	Group Art: Unknown
)	
Application No.: Unassigned)	
)	
Filed: Herewith)	Examiner: Unknown
)	
Title: <u>AN ANTENNA</u>)	

Which is a continuation of Application

Serial No. 08/351,631

Filed: December 6, 1994

PRELIMINARY AMENDMENT

Assistant Commissioner For Patents
Washington, D.C. 20231

Sir:

Applicant respectfully requests entry of this Preliminary Amendment.

In the Specification:

--CONTINUING APPLICATION DATA

This application claims priority to United States Patent Application entitled *An Antenna* invented by Oliver Paul Leisten and having Application No. 08/351,631, filed on December 6, 1994, and which is incorporated herein by reference in its entirety.--;

In the Claims:

Please cancel claims 1-37 and add the following new claims 38-92:

38. (New) A radio telephone for use at frequencies greater than 200 MHz including an antenna which comprises an electrically insulative core of a solid material having a relative dielectric constant greater than 5, and a three-dimensional antenna element structure disposed on or adjacent the outer surface of the core and defining an interior volume, the material of the core occupying the major part of the said interior volume.

39. (New) A radio telephone according to claim 38, further comprising a feeder structure which is connected to the antenna element structure and passes through the core.

40. (New) A radio telephone according to claim 38, wherein:
the core is cylindrical and has distal and proximal end faces,
the antenna includes an axial feeder structure and
the antenna element structure comprises at least two antenna elements extending from one end face in the direction of the other, and radial elements on at least the said one end face connecting the antenna elements to the feeder structure.

41. (New) A radio telephone according to claim 38, wherein the material of the core is ceramic and has a relative dielectric constant greater than 10.

42. (New) A radio telephone according to claim 38, having a feeder structure which passes through the core and is connected to the antenna element structure, wherein the core is solid with the exception of a central passage housing the feeder structure.

43. (New) A radio telephone according to claim 42, wherein the core is cylindrical, and has an axial extent at least as greater as its diameter, and with the diametrical extent of the solid material being at least 50 per cent of the said outer diameter.

44. (New) A radio telephone according to claim 38, wherein the core has a central axis and said antenna element structure comprises a plurality of antenna elements which are generally co-extensive in the axial direction.

45. (New) A radio telephone according to claim 38, wherein the core has a central axis and the antenna has a feeder structure extending through the core on the central axis, the antenna element structure comprising a plurality of antenna elements which are connected to the feeder structure at one end of the core and extend in the direction of the opposite end of the core to a common interconnecting conductor.

46. (New) A radio telephone according to claim 45, wherein the common interconnecting conductor forms a grounding conductor for the antenna element.

47. (New) A radio telephone according to claim 45, wherein the common interconnecting conductor is formed as a sleeve around a portion of the core.

48. (New) A radio telephone according to claim 47, wherein the sleeve:
is formed on an outer surface of the core and encircles the feeder structure;
has a rim to which the said antenna elements are joined; and
is connected to the feeder structure at the said opposite end of the core.

49. (New) A radio telephone according to claim 48, wherein the feeder structure has an inner conductor and a coaxial outer screen conductor, and wherein the sleeve is connected to the screen conductor.

50. (New) A radio telephone according to claim 45, wherein the antenna elements comprise helical tracks, and the sleeve is cylindrical.

51. (New) A radio telephone according to claim 38, for handheld use.

52. (New) A radio telephone having an antenna the main resonant frequency of which is in excess of 500 MHz wherein the antenna comprises an electrically insulative antenna core of a material having a relative dielectric constant greater than 5, a three-dimensional antenna element structure disposed on or adjacent the outer surface of the core and defining an interior volume, and a feeder structure which is connected to the antenna element structure and passes through the core, the material of the core occupying the major part of the said interior volume.

53. (New) A radio telephone according to claim 52, wherein the antenna element structure comprises a plurality of antenna elements defining an envelope centered on a central longitudinal axis of the antenna, and wherein the feeder structure is coincident with the said axis.

54. (New) A radio telephone according to claim 53, wherein the core is a cylinder and the antenna elements define a cylindrical envelope which is coaxial with the core.

55. (New) A radio telephone according to claim 53, wherein the core is cylindrical and is solid with the exception of an axial passage housing the feeder structure.

56. (New) A radio telephone according to claim 55, wherein the volume of the solid material of the core is at least 50 per cent of the internal volume of the envelope defined by the elements, with the elements lying on an outer cylindrical surface of the core.

57. (New) A radio telephone according to claim 53, wherein the elements comprise metallic conductor tracks bonded to the core outer surface.

58. (New) A radio telephone according to claim 52, wherein the material of the core is a ceramic.

59. (New) A radio telephone according to claim 58, wherein the relative dielectric constant of the material is greater than 10.

60. (New) A radio telephone according to claim 52, having a cylindrical core of solid material with an axial extent at least as great as its outer diameter, and with the diametrical extent of the solid material being at least 50 per cent of the outer diameter.

61. (New) A radio telephone according to claim 60, wherein the core is in the form of a tube having an axial passage of a diameter less than a half of its overall diameter, the inner passage having a conductive lining.

62. (New) A radio telephone according to claim 60, wherein the antenna element structure comprises a plurality of generally helical elements formed as metallic tracks on the outer surface of the core which are generally co-extensive in the axial direction.

63. (New) A radio telephone according to claim 62, wherein each helical element is connected to the feeder structure at one of its ends and to another of said helical elements at its other end.

64. (New) A radio telephone according to claim 63, wherein the connections to the feeder structure are made with generally radial conductive elements, and each helical element is connected to a ground or virtual ground conductor which is common to all of the helical elements.

65. (New) A radio telephone for operation at a frequency in excess of 200 MHz having an antenna which comprises a solid electrically insulative antenna core which has a central longitudinal axis and is made of a material having a relative dielectric constant greater than 5, a feeder structure extending through the core on the central axis, and, disposed on the outer surface of the core, a plurality of antenna elements which are connected to the feeder structure at one end of the core and extend in the direction of the opposite end of the core to a common interconnecting conductor.

66. (New) A radio telephone according to claim 65, wherein at least a portion of the core has a constant external cross-section in the axial direction, with the antenna elements being conductors plated on the surface of said portion.

67. (New) A radio telephone according to claim 66, wherein the antenna elements comprise a plurality of conductor elements extending longitudinally over the portion of the core having a constant external cross-section, and plurality of radial conductor elements connecting the longitudinally extending elements to the feeder structure at said one end of the core.

68. (New) A radio telephone according to claim 65, wherein the antenna includes an integral balun formed by a conductive sleeve extending over part of the length of the core from a connection with the feeder structure at the said opposite end of the core.

69. (New) A radio telephone according to claim 68, wherein the balun sleeve forms the common conductor for the longitudinally extending conductor elements, and wherein the feeder structure comprises a coaxial line having an inner conductor and an outer screen conductor, the conductive sleeve of the balun being connected at said opposite end of the core to the feeder structure outer screen conductor.

70. (New) A radio telephone according to claim 65, wherein the core is solid and has a cylindrical outer surface, and wherein the antenna elements comprise at least four longitudinally extending elements on the cylindrical outer surface and corresponding radial elements on a distal end face of the core connecting the longitudinally extending elements to the conductors of the feeder structure.

71. (New) A radio telephone according to claim 70, wherein the longitudinally extending elements are of different lengths.

72. (New) A radio telephone according to claim 71, wherein the antenna elements comprise four longitudinally extending elements, two of which are of greater length than the other two by virtue of following meandered paths on the outer surface of the core.

73. (New) A radio telephone according to claim 72, wherein each of the four longitudinally extending elements follow a respective generally helical path, the longer of the two elements each following a respective meandering course which deviates to either side of a helical center line.

74. (New) A radio telephone according to claim 70, wherein the radial elements are simple radial tracks which are all the same length.

75. (New) A telephone antenna comprising an electrically insulative core of a solid material having a relative dielectric constant greater than 5, and a three-dimensional antenna element structure disposed on or adjacent the outer surface of the core and defining an interior space, the material of the core occupying the major part of said interior space.

76. (New) An antenna for operation at frequencies in excess of 200 MHz, comprising an electrically insulative core of a solid material having a relative dielectric constant greater than 5, a three-dimensional antenna element structure disposed on or adjacent an outer surface of the core and defining an interior volume, and a feeder structure which passes through the core and provides an electrically balanced feed connection with the antenna element structure, the material of the core occupying the major part of said interior volume.

77. (New) An antenna according to claim 76, including an integral balun.

78. (New) An antenna according to claim 77, wherein the balun includes a conductive layer on said outer surface of the core.

79. (New) An antenna according to claim 78, wherein said conductive layer comprises a conductive sleeve around part of the core, and wherein the, feeder structure comprises a coaxial combination of an inner conductor and an outer screen conductor, and wherein the sleeve is connected to said outer screen conductor.

80. (New) An antenna according to claim 79, wherein the core has a central axis and wherein said antenna element structure comprises a plurality of axially co-extensive antenna elements which extend from said balanced feed connection to a rim of the sleeve.

81. (New) An antenna according to claim 80, wherein the core is cylindrical and the antenna elements are helical.

82. (New) An antenna according to claim 80, wherein at least a portion of the core is of constant cross-section, centered on said axis, and wherein said antenna elements are located on an outer surface of said portion.

83. An antenna for operation at a frequency in excess of 200 MHz comprising:
an antenna core in the form of an electrically insulative dielectric body made of a solid material having a dielectric constant greater than 5, wherein the body has an axis of symmetry and an outer surface directed outwardly from said axis, said outer surface enclosing an interior volume at least 50 per cent of which is occupied by said material,
a plurality of conductive antenna elements on said outer surface,
a feeder connection for connecting the antenna elements to a feeder,
and an integral balun.

84. An antenna according to claim 83, including a coaxial feeder having an inner conductor and an outer screen, the feeder being surrounded by said dielectric body material, wherein the balun comprises a conductive layer on said outer surface spaced from said feeder by said material.

85. (New) An antenna according to claim 84, wherein the conductive layer is formed as a sleeve around part of the core, and wherein the feeder is located on said axis and passes through the core from said feeder connection to a second said connection, at which second connection said outer screen is connected to said sleeve.

86. (New) An antenna according to claim 85, wherein the sleeve has a rim spaced from said second connection and wherein the antenna elements extend in an electrically parallel connection from said feeder connection to said rim.

87. (New) An antenna for operation at a frequency in excess of 200 MHz comprising:

an antenna core in the form of an electrically insulative dielectric body made of a solid material having a dielectric constant greater than 5, wherein the body has an axis of symmetry and an outer surface directed outwardly from said axis, said outer surface enclosing an interior volume at least 50 percent of which is occupied by said material,

a plurality of conductive antenna elements on said outer surface,

a feed connection, and

a conductive sleeve formed on said outer surface and forming a cavity surrounding part of said dielectric body.

88. (New) An antenna according to claim 87, including a coaxial feeder having an inner conductor and an outer screen, the feeder being surrounded by said dielectric body material, wherein the sleeve comprises a conductive layer on said outer surface spaced from said feeder by said material.

89. (New) An antenna according to claim 87, wherein said dielectric body is a solid cylinder having first and second end surfaces, wherein one of said end surfaces is covered by a layer of conductive material, and wherein said sleeve is connected to said layer to form a cavity

which extends from said one end surface to a sleeve rim located on said body at a position intermediate said first and second ends.

90. (New) An antenna according to claim 89, further comprising a feeder, said cavity being connected to the feeder.

91. (New) An antenna according to claim 90, wherein the feeder is located on said axis and passes through the core from said feeder connection connecting the feeder to said antenna elements to a second connection, at which second connection said outer screen is connected to said conductive layer.

92. (New) An antenna according to claim 87, including a feeder, wherein the sleeve has a rim and wherein the antenna elements extend in an electrically parallel manner from said rim to a connection with the feeder.

REMARKS

It is asserted that no new matter is added by the foregoing Preliminary Amendment.
Prosecution in due course is respectfully requested.

Respectfully submitted,

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AN ANTENNA

FIELD OF THE INVENTION

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This invention relates to an antenna for operation at frequencies in excess of 200 MHz, and in particular to an antenna which has a three-dimensional antenna element structure.

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BACKGROUND OF THE INVENTION

British Patent No. 2258776 discloses an antenna which has a three-dimensional antenna element structure by virtue of having a plurality of helical elements arranged around a common axis. Such an antenna is particularly useful for receiving signals from satellites, for example, in a GPS (global positioning system) receiver arrangement. The antenna is capable of receiving circularly polarised signals from sources which may be directly above the antenna, i.e. on its axis, or at a location a few degrees above a plane perpendicular to the antenna axis and passing through the antenna, or from sources located anywhere in the solid angle between these extremes.

While being intended mainly for reception of circularly polarised signals, such an antenna, due to its three-dimensional structure, is also suitable as an omnidirectional antenna for receiving vertically and horizontally polarised signals.

One of the disadvantages of such an antenna is that in certain applications it is insufficiently robust, and cannot easily be modified to overcome this difficulty without a performance penalty. For this reason, antennas which are to receive signals from the sky in harsh environments, such as

on the outside of an aircraft fuselage, are often patch antennas, being simply plates (generally plated metallic square patches) of conductive material mounted flush on an insulated surface which may be part of the aircraft
5 fuselage. However, patch antennas tend to have poor gain at low angles of elevation. Efforts to overcome this disadvantage have included using a plurality of differently oriented patch antennas feeding a single receiver. This technique is expensive, not only due to the numbers of
10 elements required, but also due to the difficulty of combining the received signals.

SUMMARY OF THE INVENTION

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According to one aspect of this invention an antenna for operation at a frequency in excess of 200 MHz comprises an electrically insulative antenna core of a material having a relative dielectric constant greater than 5, a three-
20 dimensional antenna element structure disposed on or adjacent the outer surface of the core and defining an interior space, and a feeder structure which is connected to the element structure and passes through the core, the material of the core occupying the major part of the said
25 interior space.

Typically the element structure comprises a plurality of antenna elements defining an envelope centred on a feeder structure which lies on a central longitudinal axis. The
30 core is preferably a cylinder and the antenna elements preferably define a cylindrical envelope which is coaxial with the core. The core may be a cylindrical body which is solid with the exception of a narrow axial passage housing the feeder. Preferably, the volume of the solid material of
35 the core is at least 50 per cent of the internal volume of the envelope defined by the elements, with the elements lying on an outer cylindrical surface of the core. The

elements may comprise metallic conductor tracks bonded to the core outer surface, for example by deposition or by etching of a previously applied metallic coating.

- 5 For reasons of physical and electrical stability, the material of the core may be ceramic, e.g. a microwave ceramic material such as zirconium-titanate-based material, magnesium calcium titanate, barium zirconium tantalate, and barium neodymium titanate, or a combination of these. The
10 preferred relative dielectric constant is upwards of 10 or, indeed, 20, with a figure of 36 being attainable using zirconium-titanate-based material. Such materials have negligible dielectric loss to the extent that the Q of the antenna is governed more by the electrical resistance of the
15 antenna elements than core loss.

A particularly preferred embodiment of the invention has a cylindrical core of solid material with an axial extent at least as great as its outer diameter, and with the
20 diametrical extent of the solid material being at least 50 per cent of the outer diameter. Thus, the core may be in the form of a tube having a comparatively narrow axial passage of a diameter at most half the overall diameter of the core. The inner passage may have a conductive lining
25 which forms part of the feeder structure or a screen for the feeder structure, thereby closely defining the radial spacing between the feeder structure and the antenna elements. This helps to achieve good repeatability in manufacture. This preferred embodiment has a plurality of
30 generally helical antenna elements formed as metallic tracks on the outer surface of the core which are generally co-extensive in the axial direction. Each element is connected to the feeder structure at one of its ends and to a ground or virtual ground conductor at its other end, the
35 connections to the feeder structure being made with generally radial conductive elements, and the ground conductor being common to all of the helical elements.

According to another aspect of the invention, an antenna for operation at a frequency in excess of 200 MHz comprises a solid electrically insulative antenna core which has a central longitudinal axis and is made of a material having a relative dielectric constant greater than 5, a feeder structure extending through the core on the central axis, and, disposed on the outer surface of the core, a radiating element structure comprising a plurality of antenna elements which are connected to the feeder structure at one end of the core and extend in the direction of the opposite end of the core to a common grounding conductor. The core preferably has a constant external cross-section in the axial direction, with the antenna elements being conductors plated on the surface of the core. The antenna elements may comprise a plurality of conductor elements extending longitudinally over the portion of the core having a constant external cross-section, and a plurality of radial conductor elements connecting the longitudinally extending elements to the feeder structure at the said one end of the core. The phrase "radiating element structure" is used in the sense understood by those skilled in the art, that is to mean elements which do not necessarily radiate energy as they would when connected to a transmitter, and to mean, therefore, elements which either collect or radiate electromagnetic radiation energy. Accordingly the antenna devices which are the subject of this specification may be used in apparatus which only receives signals, as well as in apparatus which both transmits and receives signals.

In a particularly preferred embodiment of the invention, the antenna includes an integral balun formed by a conductive sleeve extending over part of the length of the core from a connection with the feeder structure at the above-mentioned opposite end of the core. The balun sleeve may thus also form the common grounding conductor for the longitudinally extending conductor elements. In the case of the feeder structure comprising a coaxial line having an inner

conductor and an outer screen conductor, the conductive sleeve of the balun is connected at the said opposite end of the core to the feeder structure outer screen conductor.

5 The preferred embodiment of the antenna, having a core which is a solid cylinder, includes an antenna element structure comprising at least four longitudinally extending elements on the cylindrical outer surface of the core and corresponding radial elements on a distal end face of the
10 core connecting the longitudinally extending elements to the conductors of the feeder structure. Preferably, these longitudinally extending antenna elements are of different lengths. In particular, in the case of an antenna having four longitudinally extending elements, two of the elements
15 are of greater length than the other two by virtue of following meandered paths on the outer surface of the core. In the case of an antenna for circularly polarised signals, all four elements follow a generally helical path, the longer of the two elements each following a meandering
20 course which deviates, preferably, sinusoidally on each side of a helical centre line. The conductor elements connecting the longitudinally extending elements to the feeder structure at the distal end of the core are preferably simple radial tracks which may be inwardly tapered.

25

Using the above-described features it is possible to make an antenna which is extremely robust due to its small size and due to the elements being supported on a solid core of rigid material. Such an antenna can be arranged to have the same
30 low-horizon omni-directional response as the prior art antenna which is mainly air-cored, but with robustness sufficient for use as a replacement for patch antennas in certain applications. Its small size and robustness render it suitable also for unobtrusive vehicle mounting and for
35 use in handheld devices. It is possible in some circumstances even to mount it directly on a printed circuit board. Since the antenna is suitable for receiving not only

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circularly polarised signals, but also vertically or horizontally polarised signals, it may be used not only in satellite navigation receivers but also in different types of radio communication apparatus such as handheld mobile
 5 telephones, an application to which it is particularly suited in view of the unpredictable nature of the received signals, both in terms of the direction from which they are received, and the polarisation changes brought about through reflection.

10

Expressed in terms of operating wavelength in air λ , the longitudinal extent of the antenna elements, i.e. in the axial direction, is typically within the range of from 0.03λ to 0.06λ , and the core diameter is typically 0.02λ to 0.03λ .
 15 The track width of the elements is typically 0.0015λ to 0.0025λ , while the deviation of the meandered tracks from a helical mean path is 0.0035λ to 0.0065λ on each side of the mean path, measured to the centre of the meandered track. The length of the balun sleeve is typically in the range of
 20 from 0.03λ to 0.06λ .

According a third aspect of the invention, there is provided an antenna for operation at a frequency in excess of 200 MHz, wherein the antenna comprises an antenna element
 25 structure in the form of at least two pairs of helical elements formed as helices having a common central axis, a substantially axially located feeder structure having an inner feed conductor and an outer screen conductor with each helical element having one end coupled to a distal end of
 30 the feeder structure and its other end connected to a common grounding conductor, and a balun comprising a conductive sleeve located coaxially around the feeder structure, the sleeve being spaced from the outer screen of the feeder structure by a coaxial layer of insulative material having
 35 a relative dielectric constant greater than 5, with the proximal end of the sleeve connected to the feeder structure outer screen. Preferably, the axial length of the helical

elements is greater than the length of the sleeve of the balun. The sleeve conductor of the balun may also form the common grounding conductor, with each helical element terminating at a distal edge of the sleeve. In an
5 alternative embodiment, the distal edge of the sleeve is open circuit, and the common grounding conductor is the outer screen of the feeder structure.

The invention also includes, from another aspect, a method
10 of manufacturing an antenna as described above, comprising forming the antenna core from the dielectric material, and metallising the external surfaces of the core according to a predetermined pattern. Such metallisation may include
15 coating external surfaces of the core with a metallic material and then removing portions of the coating to leave the predetermined pattern, or alternatively a mask may be formed containing a negative of the predetermined pattern, and the metallic material is then deposited on the external surfaces of the core while using the mask to mask portions
20 of the core so that the metallic material is applied according to the pattern.

A particularly advantageous method of producing an antenna
25 having a balun sleeve and a plurality of antenna elements forming part of a radiating element structure, comprises the steps of providing a batch of the dielectric material, making from the batch at least one test antenna core, and then forming a balun structure, preferably without any
30 radiating element structure, by metallising on the core a balun sleeve having a predetermined nominal dimension which affects the frequency of resonance of the balun structure. The resonant frequency of this test resonator is then measured and the measured frequency is used to derive an
35 adjusted value of the balun sleeve dimension for obtaining a required balun structure resonant frequency. The same measured frequency can be used to derive at least one

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dimension for the antenna elements of the radiating element structure to give a required antenna elements frequency characteristic. Antennas manufactured from the same batch of material are then produced with a balun sleeve and 5 antenna elements having the derived dimensions.

BRIEF DESCRIPTION OF THE DRAWINGS

10 In the drawings:-

Figure 1 is a perspective view of an antenna in accordance with the invention;

15 Figure 2 is a diagrammatic axial cross-section of the antenna;

Figure 3 is a fragmentary perspective view of part of the antenna;

20

Figure 4 is a cut-away perspective view of a test resonator;

Figure 5 is a diagram of a test rig including the resonator of Figure 4; and

25

Figure 6 is a diagram of an alternative test rig.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

30

Referring to the drawings, a quadrifilar antenna in accordance with the invention has an antenna element structure with four longitudinally extending antenna elements 10A, 10B, 10C, and 10D formed as metallic conductor 35 tracks on the cylindrical outer surface of a ceramic core 12. The core has an axial passage 14 with an inner metallic lining 16, and the passage houses an axial feeder conductor

18. The inner conductor 18 and the lining 16 in this case form a feeder structure for connecting a feed line to the antenna elements 10A - 10D. The antenna element structure also includes corresponding radial antenna elements 10AR, 10BR, 10CR, 10DR formed as metallic tracks on a distal end face 12D of the core 12 connecting ends of the respective longitudinally extending elements 10A - 10D to the feeder structure. The other ends of the antenna elements 10A - 10D are connected to a common grounding conductor 20 in the form of a plated sleeve surrounding a proximal end portion of the core 12. This sleeve 20 is in turn connected to the lining 16 of the axial passage 14 by plating 22 on the proximal end face 12P of the core 12.

As will be seen from Figure 1, the four longitudinally extending elements 10A - 10D are of different lengths, two of the elements 10B, 10D being longer than the other two 10A, 10C by virtue of following a meandering course. In this embodiment, intended for circularly polarised signals, the shorter longitudinally extending elements 10A, 10C are simple helices, each executing a half turn around the axis of the core 12. On the other hand, the longer elements 10B, 10D each follow a respective meandering course which is sinusoidal in shape, deviating on either side of a helical centre line. Each pair of longitudinally extending and corresponding radial elements (for example 10A, 10AR) constitutes a conductor having a predetermined electrical length. In the present embodiment, it is arranged that the total length of each of the element pairs 10A, 10AR; 10C, 10CR having the shorter length corresponds to a transmission delay of approximately 135° at the operating wavelength, whereas each of the element pairs 10B, 10BR; 10D, 10DR produce a longer delay, corresponding to substantially 225° . Thus, the average transmission delay is 180° , equivalent to an electrical length of $\lambda/2$ at the operating wavelength. The differing lengths produce the required phase shift conditions for a quadrifilar helix antenna for circularly

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$$\text{Path length factor} = \left[\int_0^{2\pi} \frac{\phi}{\cos \{ \tan^{-1} [a n \cos(n\phi)] \}} d\phi \right] / 2\pi$$

25

ϕ is the distance along the centre line of the meandered track, expressed in radians;

30

n is the number of cycles of meandering.

With the left handed sense of the helical paths of the longitudinally extending elements 10A - 10D, the antenna has its highest gain for right hand circularly polarised signals.

5

If the antenna is to be used instead for left hand circularly polarised signals, the direction of the helices is reversed and the pattern of connection of the radial elements is rotated through 90° . In the case of an antenna
 10 suitable for receiving both left hand and right hand circularly polarised signals, albeit with less gain, the longitudinally extending elements can be arranged to follow paths which are generally parallel to the axis. Such an antenna is also suitable for use with vertically and
 15 horizontally polarised signals.

In the preferred embodiment, the conductive sleeve 20 covers a proximal portion of the antenna core 12, thereby surrounding the feeder structure 16, 18, with the material
 20 of the core 12 filling the whole of the space between the sleeve 20 and the metallic lining 16 of the axial passage 14. The sleeve 20 forms a cylinder having an axial length l_0 as show in Figure 2 and is connected to the lining 16 by the plating 22 of the proximal end face 12P of the core 12.
 25 The combination of the sleeve 20 and plating 22 forms a balun so that signals in the transmission line formed by the feeder structure 16, 18 are converted between an unbalanced state at the proximal end of the antenna to a balanced state at the axial position corresponding to the upper edge 20U of
 30 the sleeve 20. To achieve this effect, the length l_0 is such that, in the presence of an underlying core material of relatively high relative dielectric constant, the balun has an electrical length of $\lambda/4$ at the operating frequency of the antenna. Since the remainder of the feeder structure
 35 16, 18, i.e. distally of the upper edge 20U of the sleeve 20, is embedded in the core material 12 and, to a lesser extent, since the annular space surrounding the inner

conductor 18 is filled with an insulating dielectric material 17 having a relative dielectric constant greater than that of air, the feeder structure distally of the sleeve 20 has a short electrical length. Consequently, signals at the distal end of the feeder structure 16, 18 are at least approximately balanced.

The antenna has a main resonant frequency of 500 MHz or greater, the resonant frequency being determined by the effective electrical lengths of the antenna elements and, to a lesser degree, by their width. The lengths of the elements, for a given frequency of resonance, is also dependent on the relative dielectric constant of the core material, the dimensions of the antenna being substantially reduced with respect to an air-cored similarly constructed antenna.

The preferred material for the core 12 is zirconium-titanate-based material. This material has the above-mentioned relative dielectric constant of 36 and is noted also for its dimensional and electrical stability with varying temperature. Dielectric loss is negligible. The core may be produced by extrusion or pressing.

The antenna elements 10A - 10D, 10AR - 10DR are metallic conductor tracks bonded to the outer cylindrical and end surfaces of the core 12, each track being of a width at least four times its thickness over its operative length. The tracks may be formed by initially plating the surfaces of the core 12 with a metallic layer and then selectively etching away the layer to expose the core according to a pattern applied in a photographic layer similar to that used for etching printed circuit boards. Alternatively, the metallic material may be applied by selective deposition or by printing techniques. In all cases, the formation of the tracks as an integral layer on the outside of a

dimensionally stable core leads to an antenna having dimensionally stable antenna elements.

With a core material having a substantially higher relative
 5 dielectric constant than that of air, e.g. $\epsilon_r = 36$, an antenna as described above for L-band GPS reception at 1575 MHz typically has a core diameter of about 5mm and the longitudinally extending antenna elements 10A - 10D have a longitudinal extent (i.e. parallel to the central axis) of
 10 about 8mm. The width of the elements 10A - 10D is about 0.3mm and the meandered elements 10B, 10D deviate from a helical mean path by about 0.9mm on each side of the mean path, measured to the centre of the meandered track. Typically, there are five complete sinusoidal cycles of
 15 meander in each element 10B, 10D to produce the required 90° phase difference between the longer and shorter of the elements 10A - 10D. At 1575 MHz, the length of the balun sleeve 22 is typically in the region of 8mm or less. Expressed in terms of the operating wavelength λ in air,
 20 these dimensions are, for the longitudinal (axial) extent of the elements 10A - 10D: 0.042λ , for the core diameter: 0.026λ , for the balun sleeve: 0.042λ or less, for the track width: 0.002λ , and for the deviation of the meandered tracks: 0.005λ . Precise dimensions of the antenna elements
 25 10A - 10D can be determined in the design stage on a trial and error basis by undertaking eigenvalue delay measurements until the required phase difference is obtained.

In general, however, the longitudinal extent of elements 10A
 30 - 10D is between 0.03λ and 0.06λ , the core diameter between 0.02λ to 0.03λ , the balun sleeve between 0.03λ to 0.06λ , the track width between 0.0015λ to 0.0025λ , and the deviation of the meandered tracks between 0.0035λ to 0.0065λ .

35 As a result of the very small size of the antenna, manufacturing tolerances may be such that the precision with which the resonant frequency of the antenna can be

maintained is insufficient for certain applications. In these circumstances, adjustment of the resonant frequency can be brought about by removing plated metallic material from the core, e.g. by laser erosion of part of the balun sleeve 20 where it meets one or more of the antenna elements 10A - 10D as shown in Figure 3. Here, the sleeve 20 has been eroded to produce notches 28 on either side of the junction with the antenna element 10A to lengthen the element thereby reducing its resonant frequency.

10

A significant source of production variations in resonant frequency is the variability of the relative dielectric constant of the core material from batch to batch. In a preferred method of manufacturing the antenna described above, a small sample of test resonators is produced from each new batch of ceramic material, these sample resonators preferably each having an antenna core dimensioned to correspond to the nominal dimension of the core of the antenna and plated only with the balun, as shown in Figure 4. Referring to Figure 4, the test core 12T, in addition to having a plated balun sleeve 20T, also has a plated proximal face 12PT. The inner passageway 14T of the core 12T may be plated between the proximal face 12PT and the level of the upper edge 20UT of the balun sleeve 12T or, as is shown in Figure 4, it may be plated over its whole length with a metallic lining 16T. The external surfaces of the core 12T distally of the balun sleeve 20T are preferably left unplated.

The core 12T is pressed or extruded from the ceramic material batch to nominal dimensions, and the balun sleeve is plated with a nominal axial length. This structure forms a quarter-wave resonator, resonating at a wavelength λ corresponding approximately to four times the electrical length of the sleeve 20T when fed at the proximal end of the passage 14T where it meets the proximal end face 12PT of the core.

Next, the resonant frequency of the test resonator is measured. This can be performed as shown diagrammatically in Figure 5 by taking a network analyzer 30 and coupling its swept frequency source 30S to the resonator, here shown by the reference numeral 32T, using, for example, a coaxial cable 34 with the outer screen removed over the length of a short end portion 34E. End portion 34E is inserted in the proximal end of the passage 14T (see Figure 4) with the outer screen of cable 34 connected to the metallised layer 16T adjacent the proximal face 12PT of the core 12T, and with the inner conductor of the cable 34 lying approximately centrally in the passage 14T to provide capacitive coupling of the swept frequency source inside the passage 14T. Another cable 36, with its end portion 36E having the outer screen similarly cut back, is connected to the signal return 30R of the network analyzer 30 and is inserted in the distal end of the passage 14T of the core 12T. The network analyzer 30 is set to measure signal transmission between source 30S and return 30R and a characteristic discontinuity is observed at the quarter-wave resonant frequency. Alternatively, the network analyzer can be set to measure the reflected signal at the swept frequency source 30S using the single cable arrangement shown in Figure 6. Again, a resonant frequency can be observed.

25

The actual frequency of resonance of the test resonator depends on the relative dielectric constant of the ceramic material forming the core 12T. An experimentally derived or calculated relationship between a dimension of the balun sleeve 20T, for example, its axial length, on the one hand and resonant frequency on the other hand, can be used to determine how that dimension should be altered for any given batch of ceramic material in order to achieve the required resonant frequency. Thus, the measured frequency can be used to calculate the required balun sleeve dimension for all antennas to be made from that batch.

This same measured frequency, obtained from the simple test resonator, can be used to adjust the dimensions of the radiating element structure of the antenna, in particular the axial length of the antenna elements 10A - 10D plated on the cylindrical outer surface of the core distally of the sleeve 20 (using reference numerals from Figures 1 and 2). Such compensation for variations in relative dielectric constant from batch to batch may be achieved by adjusting the overall length of the core as a function of the resonant frequency obtained from the test resonator.

Using the above-described method, it may be possible, depending on the accuracy with which the frequency characteristics of the antenna are to be set, to dispense with the laser trimming process described above with reference to Figure 3. Although it is possible to use a complete antenna as a test sample, the advantage of using a resonator as described above with reference to Figure 4, i.e. without a radiating element structure, is that a simple resonance can be identified and measured in the absence of interfering resonances associated with the radiating structure.

The above-described balun arrangement of the antenna, being plated on the same core as the antenna elements, is formed simultaneously with the antenna elements, and being integral with the remainder of the antenna, shares its robustness and electrical stability. Since it forms a plated external shell for the proximal portion of the core 12, it can be used for direct mounting of the antenna on a printed circuit board, as shown in Figure 2. For example, if the antenna is to be end-mounted, the proximal end face 12P can be directly soldered to a ground plane on the upper face of a printed circuit board 24 (shown in chain lines in Figure 2). With the inner feed conductor 18 passing directly through a plated hole 26 in the board for soldering to a conductor track on the lower surface. Since the conductor sleeve 20

is formed on a solid core of material having a high relative dielectric constant, the dimensions of the sleeve to achieve the required 90° phase shift are much smaller than those of an equivalent balun section in air. The sleeve 20 also has the effect of extending the ground up to the level of the upper edge 20U where it is used for grounding the antenna elements 10A - 10D, without intervening connecting elements.

It is possible within the scope of the invention to use alternative balun and feeder structures. For example, the feeder structure may have associated with it a balun mounted at least partly externally of the antenna core 12. Thus, a balun can be effected by dividing a coaxial feeder cable into two coaxial transmission lines acting in parallel, one being longer than the other by an electrical length of $\lambda/2$, the other ends of these parallel-connected coaxial transmission lines having their inner conductors connected to a pair of inner conductors passing through the passageway 14 of the core 12 to be connected to respective pairs of the radial antenna elements 10AR, 10DR; 10BR, 10CR.

As another alternative, the antenna elements 10A - 10D can be grounded directly to an annular conductor at the proximal edge of the cylindrical surface of the core 12, a balun being formed by an extension of the feeder structure having a coaxial cable formed into, for example, a spiral on the proximal end face 12P of the core, so that the cable spirals outwardly from the inner passage 14 of the core to meet the annular conductor at the outer edge of the end face 12P where the screen of the cable is connected to the annular conductor. The length of the cable between the inner passageway 14 of the core 12 and the connection to the annular ring is arranged to be $\lambda/4$ (electrical length) at the operating frequency.

35

All of these arrangements configure the antenna for circularly polarised signals. Such an antenna is also

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sensitive to both vertically and horizontally polarised signals, but unless the antenna is specifically intended for circularly polarised signals, the balun arrangement can be omitted. The antenna may be connected directly to a simple
5 coaxial feeder, the inner conductor of the feeder being connected to all four radial antenna elements 10AR - 10DR at the upper face of the core 12, and the coaxial feeder screen being coupled to all four longitudinally extending elements 10A - 10D via radial conductors on the proximal face 12P of
10 the core 12. Indeed, in less critical applications, the elements 10A - 10D need not be helical in their configuration, but it is merely sufficient that the antenna element structure as a whole, comprising the elements and their connections to the feeder structure, should be a
15 three-dimensional structure so as to be responsive to both vertically and horizontally polarised signals. It is possible, for example, to have an antenna element structure comprising two or more antenna elements each with an upper radial connecting portion as in the illustrated embodiment,
20 but also with a similar lower radial connecting portion and with a straight portion connecting the radial portions, parallel to the central axis. Other configurations are possible. This simplified structure is particularly applicable for cellular mobile telephony. A notable
25 advantage of the antenna for handheld mobile telephones is that the dielectric core largely avoids detuning when the antenna is brought close to the head of the user. This is in addition to the advantages of small size and robustness.

30

As for the feeder structure within the core 12, in some circumstances it may be convenient to use a pre-formed coaxial cable inserted inside the passage 14, with the cable emerging at the end of the core opposite to the radial
35 elements 10AR to 10DR to make a connection with receiver circuitry, for example, in a manner other than by the direct connection to a printed circuit board described above with

reference to Fig. 2. In this case the outer screen of the cable should be connected to the passage lining 16 at two, preferably more, spaced apart locations.

- 5 In most applications the antenna is enclosed in a protective envelope which is typically a thin plastics cover surrounding the antenna either with or without an intervening space.

- 10 What is claimed is:-

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1. An antenna for operation at a frequency in excess of 200 MHz, comprising an electrically insulative antenna core of a material having a relative dielectric constant greater than 5, a three-dimensional antenna element structure disposed on or adjacent the outer surface of the core and defining an interior volume, and a feeder structure which is connected to the element structure and passes through the core, the material of the core occupying the major part of the said interior volume.

2. An antenna according to claim 1, wherein the antenna element structure comprises a plurality of antenna elements defining an envelope centred ^{ON} a central longitudinal axis of the antenna, and wherein the feeder structure is coincident with the said axis.

3. An antenna according to claim 2, wherein the core is a cylinder and the antenna elements define a cylindrical envelope which is coaxial with the core.

4. An antenna according to claim 2, wherein the core is a cylindrical body which is solid with the exception of an axial passage housing the feeder structure.

25

5. An antenna according to claim 4, wherein the volume of the solid material of the core is at least 50 per cent of the internal volume of the envelope defined by the elements, with the elements lying on an outer cylindrical surface of the core.

30

6. An antenna according to claim 2, wherein the elements comprise metallic conductor tracks bonded to the core outer surface.

35

7. An antenna according to claim 1, wherein the material of the core is a ceramic.

9. An antenna according to claim 1, having a cylindrical
5 core of solid material with an axial extent at least as
great as its outer diameter, and with the diametrical extent
of the solid material being at least 50 per cent of the
outer diameter.

15 11. An antenna according to claim 9, wherein the antenna element structure comprises a plurality of generally helical antenna elements formed as metallic tracks on the outer surface of the core which are generally co-extensive in the axial direction.

13. An antenna for operation at a frequency in excess of
200 MHz, comprising a solid electrically insulative antenna
core which has a central longitudinal axis and is made of a
material having a relative dielectric constant greater than
5, a feeder structure extending through the core on the
central axis, and, disposed on the outer surface of the
core, a plurality of antenna elements which are connected to
the feeder structure at one end of the core and extend in

the direction of the opposite end of the core to a common grounding conductor.

14. An antenna according to claim 13, wherein the core has
5 a constant external cross-section in the axial direction,
with the antenna elements being conductors plated on the
surface of the core.

15. An antenna according to claim 14, wherein the antenna
10 elements comprise a plurality of conductor elements
extending longitudinally over the portion of the core having
a constant external cross-section, and a plurality of radial
conductor elements connecting the longitudinally extending
elements to the feeder structure at the said one end of the
15 core.

16. An antenna according to claim 15, including an integral
balun formed by a conductive sleeve extending over part of
the length of the core from a connection with the feeder
20 structure at the said opposite end of the core.

17. An antenna according to claim 16, wherein the balun
sleeve forms the common grounding conductor for the
longitudinally extending conductor elements, and wherein the
25 feeder structure comprises a coaxial line having an inner
conductor and an outer screen conductor, the conductive
sleeve of the balun being connected at the said opposite end
of the core to the feeder structure outer screen conductor.

30

18. An antenna according to claim 13, wherein the core is
a solid cylinder, and wherein the antenna elements comprise
at least four longitudinally extending elements on the
cylindrical outer surface of the core and corresponding
35 radial elements on a distal end face of the core connecting
the longitudinally extending elements to the conductors of
the feeder structure.

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19. An antenna according to claim 18, wherein the longitudinally extending elements are of different lengths.

20. An antenna according to claim 19, wherein the antenna
5 elements comprise four longitudinally extending elements, two of which are of greater length than the other two by virtue of following meandered paths on the outer surface of the core.

10 21. An antenna according to claim 20, wherein each of the four longitudinally extending elements follow a respective generally helical path, the longer of the two elements each following a respective meandering course which deviates to either side of a helical centre line.

15 22. An antenna according to claim 18, wherein the radial elements are simple radial tracks which are all the same length.

20 23. An antenna according to claim 13, having a plurality of antenna element with a longitudinal extent in the range of from 0.03λ to 0.06λ , the core diameter being in the range of from 0.02λ to 0.03λ , where λ is the operating wavelength of the antenna in air.

25 24. An antenna according to claim 23 and claim 16, wherein the length of the balun sleeve is in the range of from 0.03λ to 0.06λ .

30 25. An antenna for operation at a frequency in excess of 200 MHz, comprising an antenna element structure in the form of at least two pairs of helical elements formed as helices having a common central axis, a substantially axially located feeder structure having an inner feed conductor and
35 an outer screen conductor with each helical element having one end coupled to a distal end of the feeder structure and its other end connected to a common grounding conductor, and

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a balun comprising a conductive sleeve located coaxially around the feeder structure, the sleeve being spaced from the outer screen of the feeder structure by a coaxial layer of insulative material having a relative dielectric constant greater than 5, with the proximal end of the sleeve connected to the feeder structure outer screen.

26. An antenna according to claim 25, wherein the sleeve conductor of the balun forms the common grounding conductor, with each helical element terminating at a distal edge of the sleeve.

27. An antenna according to claim 25, wherein the distal edge of the sleeve is open circuit, and the common grounding conductor is the outer screen of the feeder structure.

28. Radio communication apparatus having an antenna according to claim 13, wherein the antenna is mounted directly on a printed circuit board forming part of the apparatus.

29. A method of manufacturing an antenna as claimed according to claim 13, comprising forming the antenna core from the dielectric material, metallising the external surfaces of the core according to a predetermined pattern.

30. A method according to claim 29, wherein the metallisation step includes coating the external surfaces of the core with a metallic material and removing portions of the coating to leave the predetermined pattern.

31. A method according to claim 29, wherein the metallisation step includes forming a mask containing a negative of the said predetermined pattern and depositing a metallic material on the external surfaces of the core while using the mask to mask portions of the core so that the

metallic material is applied according to the predetermined pattern.

32. A method of manufacturing a plurality of antennas as
5 claimed in claim 16 comprising:-

- providing a batch of the dielectric material;
- making from the batch at least one test antenna core;
- forming a balun structure by metallising on the core a
balun sleeve having a predetermined nominal dimension which
10 affects the frequency of resonance of the balun structure;
- measuring the resonant frequency to derive an adjusted
value of the balun sleeve dimension for obtaining a required
balun structure resonant frequency, and to derive at least
one dimension for the antenna elements giving a required
15 antenna elements frequency characteristic; and
- manufacturing from the same batch of material a
plurality of antennas with a balun sleeve and antenna
elements having the derived dimensions.

20 33. A method according to claim 32, wherein the test core
is cylindrical and is made with an axial passage, and the
passage is metallised over a section thereof which is
coextensive with the balun sleeve.

25 34. A method according to claim 32, wherein the test core
is cylindrical and is made with an axial passage, and the
passage is metallised over the whole of its length.

30 35. A method according to claim 33 or claim 34, wherein the
said sleeve dimension is its axial length.

36. A method according to claim 33 or claim 34, wherein the
said dimension for the antenna elements is the length of at
least some of the antenna elements.

35

37. A method according to claim 33 or claim 34, wherein the
said dimension for the antenna elements is the axial extent

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ABSTRACT OF THE DISCLOSURE

An antenna for use at UHF and upwards has a cylindrical ceramic core with a relative dielectric constant of at least 5. A three-dimensional radiating element structure, consisting of helical antenna elements on the cylindrical surface of the core and connecting radial elements on a distal end face of the core, is formed by conductor tracks plated directly on the core surfaces. At the distal end face the elements are connected to an axially located feed structure in a plated axial passage of the core. The antenna elements are grounded on a plated sleeve covering a proximal part of the core which, in conjunction with the feeder structure, forms an integral balun for matching to an unbalanced feeder.

Since the ceramic core fills the major part of the interior volume defined by the radiating element structure, the antenna is very much smaller than an air-cored antenna. It is also mechanically robust and electrically stable.

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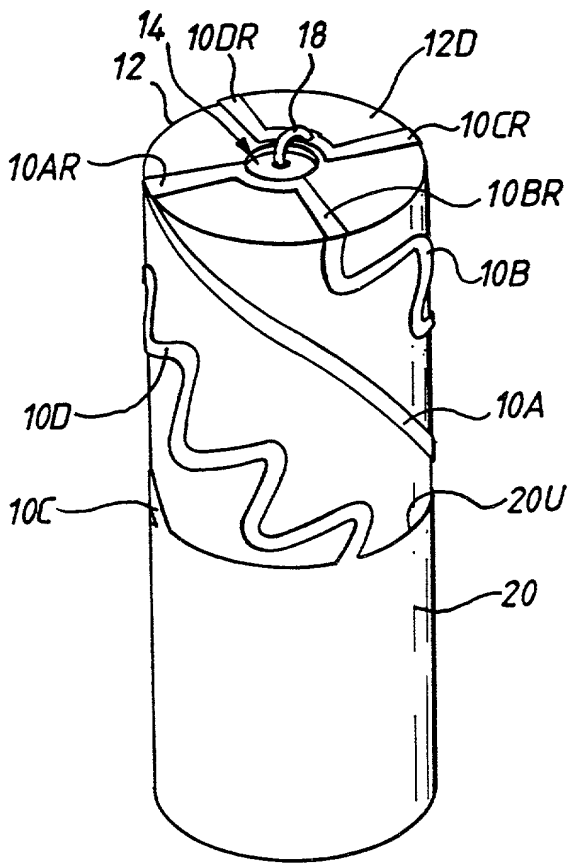


Fig.1.

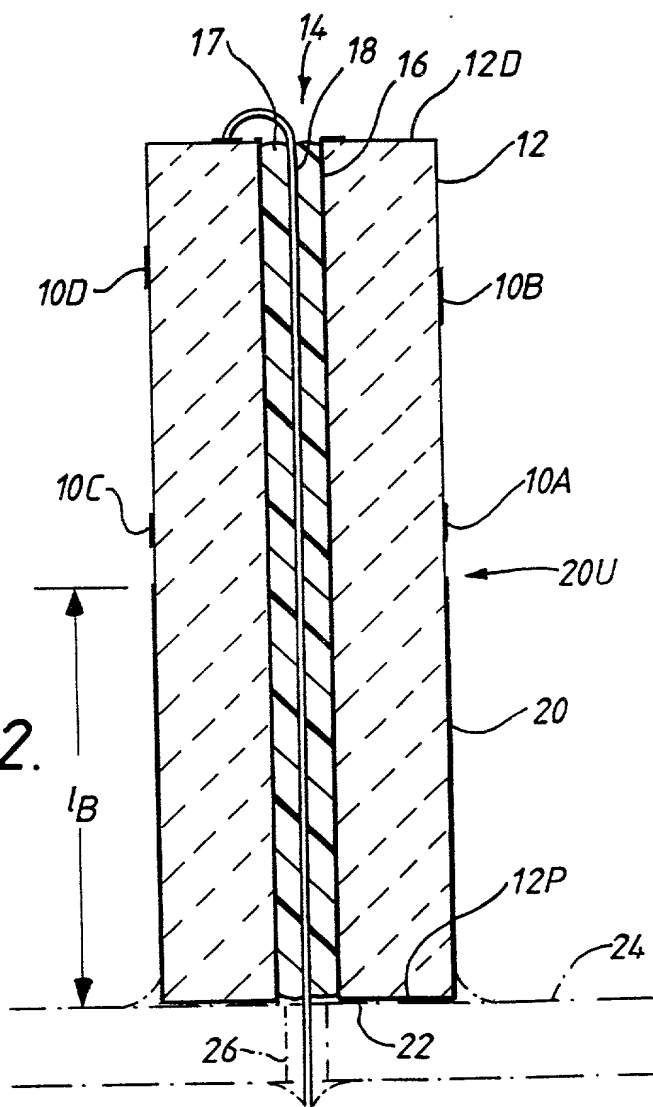


Fig.2.

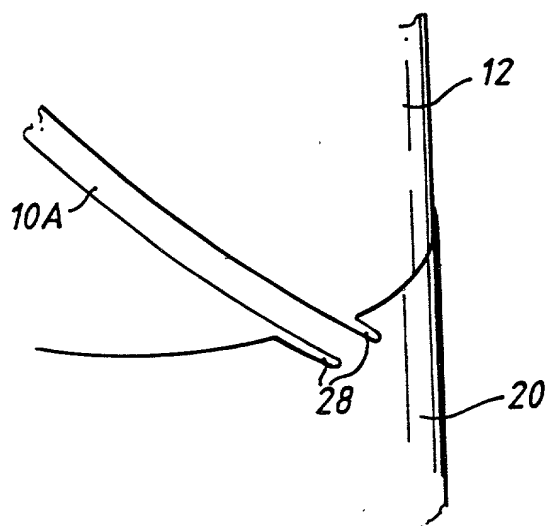


Fig. 3.

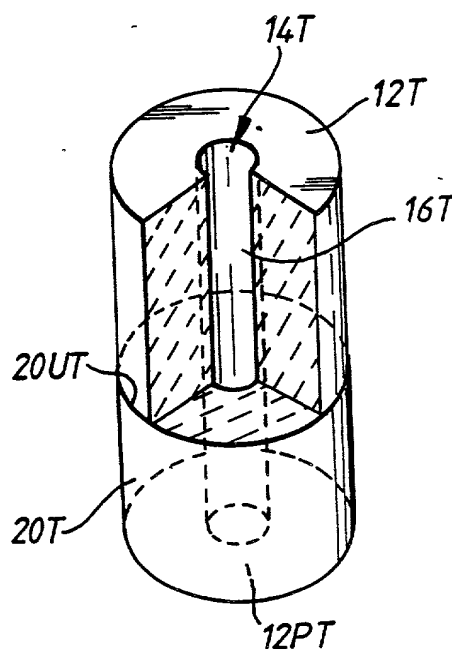


Fig. 4.

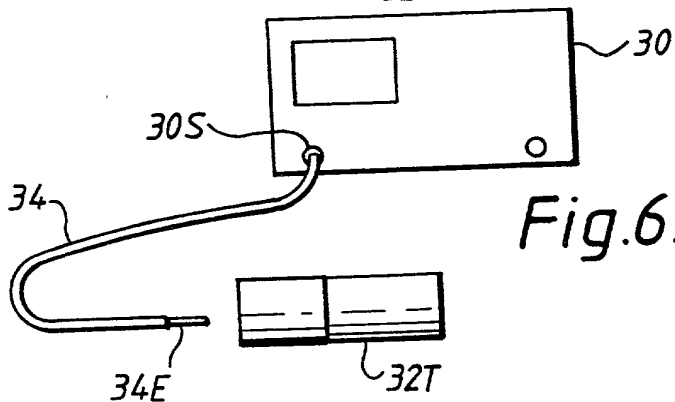
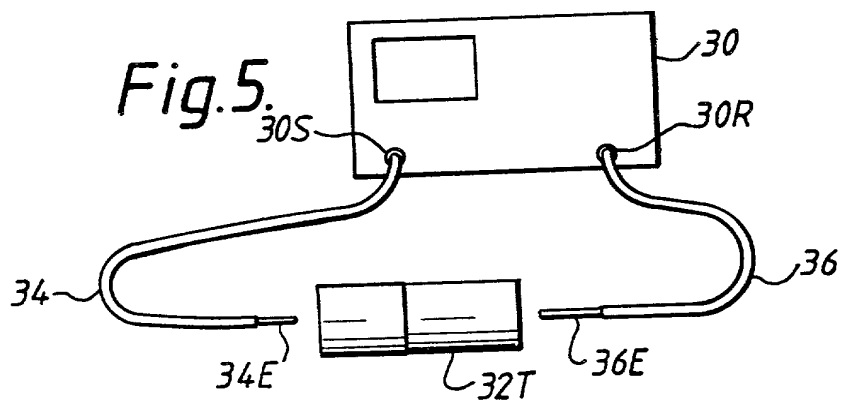


Fig. 6.

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DECLARATION
and POWER OF ATTORNEY

☒ ORIGINAL
☐ CONTINUATION
☐ DIVISIONAL

As a below named inventor, I declare that the information given herein is true, that I believe that I am the original, first and sole inventor if only one name is listed at 1 below, or a joint inventor if plural inventors are named below at 1-4, of the invention entitled:

AN ANTENNA

Which is described and claimed in:

☒ the attached specification or

☐ the specification in application Serial No. _____ filed _____ ☐ as amended on _____ (if applicable)

and for which a patent is sought, and that my residence, post office address and citizenship are as stated below next to my name.

I acknowledge my duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations §1.56(a). I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

PRIOR FOREIGN APPLICATION(S)

COUNTRY	APPLICATION NUMBER	DATE OF FILING Month Day Year	PRIORITY CLAIMED UNDER 35 U.S.C. 119
UNITED KINGDOM	9417450.5	08 25 94	YES <input checked="" type="checkbox"/> NO <input type="checkbox"/>
			YES <input type="checkbox"/> NO <input type="checkbox"/>

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application.

(Application Serial No.) (Filing Date) (Status)

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or Agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

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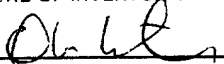
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4	Name of Inventor	LAST NAME	FIRST NAME	MIDDLE NAME	Residence: CITY	STATE or COUNTRY
	Post Office Address					CITIZENSHIP

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

SIGNATURE OF INVENTOR 1 	SIGNATURE OF INVENTOR 2
DATE 28th NOVEMBER 1994	DATE
SIGNATURE OF INVENTOR 3	SIGNATURE OF INVENTOR 4
DATE	DATE

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AB

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

PATENT APPLICATION

IN RE PATENT APPLICATION OF)

Examiner: Ho. T.

Oliver P. Leisten)

Group Art Unit: 2514

Application No. 08/351,631)

Filing Date: December 6, 1994)

Title: *An Antenna*)

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POWER OF ATTORNEY BY ASSIGNEE
TO EXCLUSION OF INVENTOR UNDER 37 C.F.R. § 3.71
WITH REVOCATION OF PRIOR POWERS

Commissioner of Patents
and Trademarks
Washington, D.C. 20231

Sir:

The undersigned ASSIGNEE of the entire interest in the above-identified application for letters patent hereby appoints Paul Davis, Reg. No. 29,294, Mark A. Haynes, Reg. No. 30,846, David J. Weitz, Reg. No. 38,362, Kent R. Richardson, Reg. No. 39,443, Charles C. Cary, Reg. No. 36,764, Michael J. Murphy, 37,404, George A. Willman, 41,378, Peter Eng, Reg No. 39,666, John Bruckner, Reg. No. 35,816, David Abraham, Reg. No. 39,554, and to prosecute this application and transact all business in the United States Patent and Trademark Office in connection therewith and hereby revokes all prior powers of attorney; said appointment to be to the exclusion of the inventors and the inventors' attorneys in accordance with the provisions of 37 C.F.R. § 3.71.

The following evidentiary documents establish a chain of title from the original owner to the Assignee:

— a copy of an Assignment attached hereto, which Assignment has been (or is herewith) forwarded to the Patent and Trademark Office for recording; or

X the Assignment recorded on December 6, 1994, frames 7290/0389.

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Pursuant to 37 C.F.R. § 3.73(b) the undersigned Assignee hereby states that evidentiary documents have been reviewed and hereby certifies that, to the best of ASSIGNEE's knowledge and belief, title is in the identified ASSIGNEE.

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ASSIGNEE: SYMMETRICOM, INC.

Name: William D. Rasdal
(Signature)

Name: William D. Rasdal
(Print or Type)

Title: Chairman of the Board & CEO

Date: December 2, 1997